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BUILDING THE DAML ELECTRONIC COMMERCE DOMAIN

FINAL TECHNICAL REPORT

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14. ABSTRACT

The inability of the Web applications built on the prevalent hypertext markup language (HTML) infrastructure to meaningfully share information has greatly hindered electronic commerce. These applications do not adequately analyze and semantically structure the overwhelming amounts of data returned to a user through a keyword, full-text, or other search. The inadequacy of the existing Web tools to semantically structure information has caused staggering costs and productivity losses in the business-to-business (B2B) electronic commerce domain. Agent technology provides an efficient approach to achieving interoperabilty of Web applications and offers a framework for developing Semantic Web tools that enable seamless electronic commerce. This project has built a B2B eCommerce Gateway (DAMLGate) on the DARPA agent markup language (DAML) infrastructure. DAMLGate enables interoperability and linking of Web documents to machine-readable ontologies. The initial version of DAMLGate facilitates distributed agile manufacturing processes in the highly automated and dynamic electronics assembly environment.

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Abstract

The inability of applications built on the prevalent Internet-standard – the Hypertext Markup Language (HTML), to interoperate and meaningfully share information has greatly hindered electronic commerce. These applications do not adequately analyze nor semantically structure the overwhelming amounts of data returned to a user through a keyword or other search. The inadequacy of the current Web tools to semantically structure information has caused staggering productivity losses and other costs.

Emerging agent-based Semantic Web tools have extended HTML, enabling data interoperability and facilitating the derivation of semantically rich information from Web resources. Agent technology appears to be the best approach for developing solutions to the interoperability and other challenges that impede electronic commerce, intelligence gathering and distribution, business logistics, enterprise applications integration, etc. The opportunities for commercial exploitation of the emerging technologies are pervasive in the highly disaggregated electronics industry where enterprises constantly handle thousands of different-size parts and products in various stages of production, originating from widely dispersed vendors. The enterprises are often confronted with the complex logistical challenge of determining the best path in its value chain for each part. This challenge is further complicated by the unpredictable behavior of the industry's value chain as participants interact in a rapidly changing environment.

This project has built an agent-driven business-to-business (B2B) eCommerce gateway (DAMLGate) for global collaboration and exchange in the electronics industry. DAMLGate enables interoperability and linking of Web documents to machine-readable ontologies. It is built to facilitate distributed agile manufacturing processes in the highly automated and dynamic electronics assembly environment. The DAMLGate architecture enables flexible, deep, and meaningful collaboration between and within participating enterprises in the electronics and other industries. The agent tools driving DAMLGate facilitate access and add semantic structure to the content of Web-based documents and databases.

Future research will focus on building an open, dynamic eCommerce architecture and developing advanced e-business tools that provide unified access to fully described business content and also facilitate the derivation of the optimum paths for various components in the supply chain. The enhanced agent tools and intelligent manufacturing systems will facilitate the coordination of production schedules with shipment logistics and the derivation of the optimum path for each part in the value chain.

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SUMMARY

Bowie State University (BSU) has built an agent-driven eCommerce gateway (DAMLGate) on the evolving Semantic Web infrastructure. The DAMLGate project was sponsored by the Defense Advanced Research Projects Agency (DARPA) and directed by the Office of Naval Research (ONR). The project addressed the challenges to eCommerce arising from the lack of interoperability of most Web applications with enterprise systems as well as other problems inherent in the current Web infrastructure. The inefficiencies associated with the inability of applications to communicate and meaningfully share relevant information greatly impede eCommerce and pose a major challenge to intelligence production and distribution and also other efforts that rely on timely retrieval and dissemination of critical information.

Businesses and other users of the World Wide Web (WWW) have incurred staggering productivity losses and other related costs frustratingly searching for meaningful information from the massive volumes of diverse and highly unstructured data that most Web applications cannot properly analyze and effectively integrate. The lack of a common human- and machine-readable language or format makes it difficult for the applications to integrate and semantically structure the required information.

Solving this information discovery and management challenge is perceived by DARPA and other organizations as one of the most effective ways of impacting production and other costs. Advances in knowledge representation (KR) and agent-based computing (ABC) have propelled the search for a common human- and machine-readable language for effective classification and representation of information. The evolving DARPA Agent Markup Language (DAML) represents semantic relations in machine-readable manner and enables users to provide machine-readable semantic annotations (ontologies) for specific communities of interest. Agent technology provides an effective approach to the interoperability and other challenges. DAML enables semantic interoperability at the level syntactic interoperability is currently attained in the Extensible Markup Language (XML). It provides the metadata schema for DAMLGate.

This is one of the projects awarded in the preliminary phase of the DAML Program. It is a multi-stage project whose thrust is to build the DAML eCommerce domain. This report presents the results of the first stage of the project. The current focus is on building the infrastructure for a DAML-driven business-to-business (B2B) eCommerce.

Project Objectives

The specific goals sought by this project include application of emerging Web technologies for enhanced information discovery and integration to:

- Reduce the time and cost associated with location, identification, and structuring of eCommerce information derived from the Web.
- Provide virtual catalogs of marked up, precisely described, and constantly updated eCommerce transactions and documents.

Derivable Benefits

This project, among other things:

- Provides a robust and easily customizable platform that can support a broad spectrum of commercial processes associated with defense and other industry groups. DAMLGate fully captures semantically rich descriptions of commercial products and services as well as the relationships between them.
- Enables constant derivation of libraries of rich, cross-enterprise ontology assets.
- Improves the retrieval of information with high intelligence density from Web sources through search and other mechanisms.
- Reduces product acquisition or service delivery time and cost by significantly improving productivity in source selection and component design and purchasing, as well as in the identification of relevant products, processes, and services.
- Increases interoperability between enterprise systems and Web applications.

Technical Approach

This project adopted an integrative agent-based methodological framework in the building of the DAML eCommerce gateway. Our overall technical approach combined the salient features of object-oriented and knowledge engineering methodologies with formal approaches to system development. Agent technology provides an efficient approach to achieving interoperability of Web applications and offers a framework for developing Semantic Web tools that will enable seamless eCommerce.

Results

A major achievement in the first stage of this project is the construction and deployment of the initial version of the DAMLGate solution suite. The gateway is located on the Web at http://damlgate.bowiestate.edu. The site was populated with information from a few e-marketplaces that reflect the diversity in the electronics industry as metadata in agile catalogs. We expanded the seed ontology to reveal an extensive hierarchy of dependencies that is dynamically generated in the gateway. The attractiveness of DAMLGate is that additional programming is not required to expand or update the ontology hierarchy. A more detailed discussion of the technical highlights and other accomplishments of this project are available in Section 3 of this report as well as in other project publications.

This and other DAML projects have demonstrated that agent technology is indeed the best approach to achieving semantic interoperability between Web applications. Agent-based frameworks used in various DAML projects have greatly enhanced agent discovery, reuse, and interoperability. The enormous economic and other benefits derivable from the DAML tools and services provided by this project are driving major suppliers and other trading partners to DAMLGate and related initiatives, and will create a sustainable market for the digital services embedded in Semantic Web technologies.

The DAMLGate experiment has presented an innovative way of discovering, using, and interpreting Web resources. It provides a "one-stop shopping" to computer and other electronics equipment builders through the eGateway portal.

Conclusions and Recommendations

Agent technology is a promising approach to achieving semantic interoperability of Web applications and facilitating intelligence gathering, electronic commerce, and other application areas. It has been used to support both crawling and automatic indexing functions. This project recommends a Java-based agent platform for the development of eCommerce and other agile Web applications.

1. INTRODUCTION

1.1 Project Background

The World Wide Web (WWW) has revolutionized the way most organizations operate. An increasing number of public- and private sector organizations constantly seek critical operational information from the Web and other distributed knowledge bases. It is often a tedious task to find relevant information on a subject even within a single site, using existing Internet technologies. Information retrieval from multiple, disaggregated sources is quite daunting, very frustrating and inefficient. Available Web tools, such as search engines and corporate portals tend to overload users with massive volumes of diverse, unstructured information that have low intelligence density. Current Web technologies can only explore fewer than 30 percent of the relevant Web resources. This situation largely stems from the inability of widely varied Web and enterprise applications to interoperate and share meaningful information. The problem is worsening as Web resources continue to grow rapidly in size and diversity.

Some have argued that the lack of standards for interoperation of differently configured enterprise and eCommerce applications is a more critical constraint on eCommerce than the reliability or security of the Internet [1]. A study by the Science Applications International Corporation (SAIC) revealed that up to 40% of the time spent in the design of complex products, such as missiles, naval vessels, aircraft and other major weapon systems, was spent on information search and retrieval [2]. The lack of a common human- and machine-readable language and other standards for data interoperation made it difficult to identify and structure critical production information, or to reuse or modify existing components in new designs, and further complicated the distribution of such information across the supply chain. The impact on productivity and related costs was staggering since, according to the study, more than 50 percent of the development and production time and cost of most large systems projects was below the prime contractor level in the supply chain [2].

The rapid growth of eCommerce has intensified the need for efficient information discovery and management as well as strengthened the interest in interoperability of Web applications. The quest for increased intelligence density of information derived from Web documents has engendered several initiatives to develop appropriate Internet tools and languages that extend the content markup capability of XML.

Advances in knowledge representation (KR) and agent-based computing (ABC) have propelled the search for a common human- and machine-readable language for effective classification and representation of information. Agent technology provides an effective approach to the interoperability and other challenges that plague the current Web. DARPA and the World Wide Web Consortium (W3C) are leading the initiative toward the establishment of the Semantic Web – a knowledge-based Web of machine-readable information and automated services [3]. By explicitly representing the semantics underlying data, programs, pages, and other Web resources, the Semantic Web will deliver a qualitatively higher level of service to the end user.

As part of its agent-based computing thrust, DARPA launched the DARPA Agent Markup Language (DAML) Program in October 2000. The DAML Program is building a general-purpose language and the toolset needed to fulfill the bold vision of the Semantic Web [4]. DAML represents semantic relations in machine-readable manner and enables users to provide machine-readable semantic annotations (ontologies) for specific communities of interest. It facilitates access and adds semantic structure to the content of Web-based documents and databases. DAML and a parallel European Union's initiative, the Ontology Inference Layer (OIL) evolved later that year as a joint standard (DAML+OIL) for integrating ontologies with existing and emerging Web standards. Both DAML and OIL are properly grounded in W3C standards such as Resource Description Framework (RDF)/RDF-Schema and XML/XML-Schema [5].

DAML+OIL is widely recognized as a sound foundation for the Semantic Web. It is currently used for a broad spectrum of applications, ranging from military intelligence gathering to electronic commerce and business process management. The emerging standard for the Semantic Web, the Web Ontology Language (OWL), is derived from DAML+OIL and builds upon the Resource Description Framework. OWL is a markup language for publishing and sharing ontologies (defining term vocabularies and term relationships) on the World Wide Web. OWL provides an XML vocabulary to define classes, their properties and their relationships among classes. It enables expression of much richer relationships than RDF-S, thus yielding a much enhanced inferencing capability. Also, OWL facilitates a much greater degree of inference making than can be achieved with RDF-S. Heflin and others have been specified OWL's usage scenarios, goals and requirements [6].

The applications that will drive the acceptance of DAML+OIL are those that cannot be accomplished within the limitations of HTML and XML. These applications include:

- Intelligence analysis and production
- Military planning and operations
- Sensor fusion
- Business process management
- Intelligent manufacturing
- Electronic commerce

This is one of the projects awarded in the preliminary phase of the DAML Program. It is a multi-stage project whose thrust is to build the DAML eCommerce domain. In particular, BSU has built a framework for implementation of B2B and other eCommerce on the DAML+OIL infrastructure. It has built and deployed the DAML eCommerce gateway (DAMLGate), using emerging DAML+OIL and DAML-S technologies. This report presents the results of the first stage of the project. The current focus is on building the infrastructure for a DAML-driven business-to-business (B2B) eCommerce.

This project is the first stage in a proposed multi-stage thrust to build a robust architecture on which to erect the DAML eCommerce domain. It was undertaken in pursuit of the mission of the DAML Program: "to create technologies that will enable software agents to dynamically identify and understand information sources, and to provide interoperability between agents in a semantic manner" [7]. Our DAML-driven eCommerce Gateway (DAMLGate) – an e-portal for global collaboration in the electronics and other industries, has advanced the longer-term vision of the DAML Program and has extended other research and development projects within the DAML Program. Subsequent versions of DAMLGate will support business-to-customer and other electronic commerce models and facilitate the discovery of rich semantic descriptions of commercial products and services.

The B2B e-market opportunities are rapidly expanding and the growing clientele includes both government agencies and commercial businesses in every sector of the U. S. and other national economies. The opportunities are prevalent in the disaggregated electronics industries where enterprises constantly handle thousands of different-size parts and products in various stages of production, originating from widely dispersed vendors. The enterprises are often confronted with the complex logistical challenge of determining the best path in its value chain for each part. This challenge is further complicated by

the unpredictable behavior of the industry's value chain as participants interact in a rapidly changing environment. The situation calls for an unprecedented level of collaboration, and the number of electronics and other manufacturers embracing collaboration is growing by leaps and bounds worldwide.

In the trend towards horizontal integration, most enterprises in the electronics industry are focusing on their core competencies and are outsourcing their non-core activities. This has created a rapidly growing market for collaboration among the global trading partners who coordinate their efforts to deliver a final product, service or solution. But the technology infrastructure underlying the existing e-market platforms will not enable full collaboration between and within participating enterprises. We have deployed an advanced, agent-driven eHub (DAMLGate) for global collaboration in the electronics industry that is built on the Semantic Web infrastructure. The DAMLGate architecture enables flexible, deep, and meaningful collaboration between and within participating enterprises.

1.2 Purpose and Scope

The primary purpose of this project is to facilitate the transition of the technologies emerging from the DAML Program to commercial markets, and to enable large-scale deployment of eCommerce platforms that provide semantically structured information and interoperable applications. Several tools that extend the prevalent Internet-standard (HTML) have already been developed within and outside the DAML Program. These tools can be used to tag information sources and enable semantically rich structures to be defined, so as to support the declaration and publication of products, processes, companies, technologies, skills and their key attributes by the participants in e-Commerce transactions.

This project applied the emerging Semantic Web technologies to enhance information discovery and integration and facilitate value-chain management in the electronics and other industries. The specific objectives sought by the project include to:

- Reduce the time and cost associated with location, identification, and structuring of e-commerce information derived from the Web.
- Provide virtual catalogs of marked up, precisely described, and constantly updated e-commerce transactions and documents.

1.3 Document Overview

The major elements of this report are organized into three parts. The first part includes the front matter: the title page, notices, abstract, table of content, and list of figures. The main text comprises six sections that are presented in the second part of the report. In the first section (summary), we present an overview of the problem domain addressed by the project, and succinctly reveal the technical highlights, findings, conclusions and recommendations of the study. The project background as well as the purpose and scope of the study are discussed in section 1 (introduction). The research process and the assumptions underlying the study are presented in section 2 (methods, assumptions, and procedures). The results and major accomplishments of the study are discussed in section 3 (results and discussion). The concluding remarks, recommendations, and future directions of the study are presented in section 4 (conclusions and recommendations). In section 5 (references) we cite the sources of information presented in this report. The third part of the report (back matter) lists the literature and resources relevant to this research as well as the symbols, abbreviations, and acronyms used in this report.

2. METHODS, ASSUMPTIONS and PROCEDURES

2.1 Technical Approach

The central premise of this project is that agent technology provides an efficient approach to achieving interoperability of Web applications and offers a framework for developing Semantic Web tools that will enable seamless eCommerce. Agent technology has been successfully used to improve distributed intelligent manufacturing, supply chain management, manufacturing planning, scheduling and production control, inventory management, as well as holonic and other manufacturing systems [8]. This project adopted an integrative agent-based methodological framework in building the DAMLGate. Our overall technical approach combined the salient features of object-oriented and knowledge engineering methodologies with formal approaches to system development [9,10,11]. The DAMLGate methodological framework conforms to the Institute of Electrical and Electronics Engineers (IEEE) Standard 1074-1997 [12], and comprises four essential technology layers: ontology, process, knowledge, and tools.

The framework is illustrated in Figure 1 below.

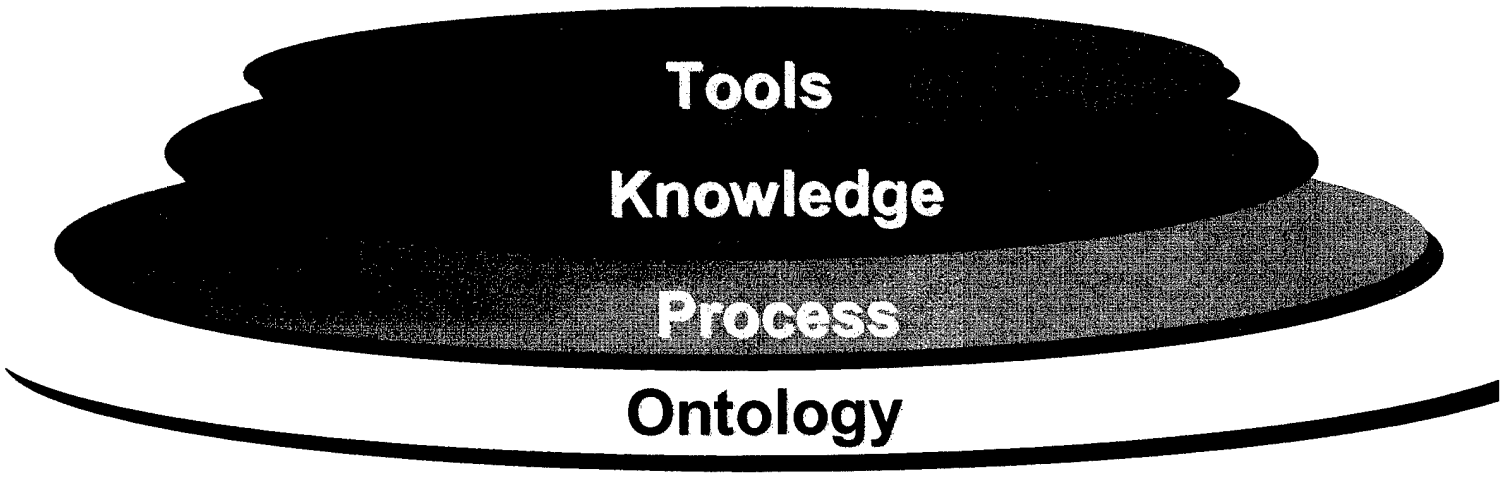

Figure 1. The DAMLGate Methodological Framework.

The ontology layer identifies and structures the B2B eCommerce environment and is the base or foundation on which DAMLGate is erected. The process layer models the business and other processes and specifies the policies and guiding principles in B2B eCommerce. The key process areas (KPAs) that must be established for effective delivery of goods and services in the value chain are identified and structured in this layer. The knowledge base for building ontologies and fostering continuous process improvement is provided in the knowledge layer. This layer also includes analytical techniques and other methods that facilitate and support the other framework layers. The toolkits needed to provide automated or other support for the knowledge, process, and ontology layers are described in the tools layer. The toolkits comprising the tools layer include [13]:

- *Data Access Toolkit* – supports access to databases and other external data sources
- *Knowledge Base Toolkit* – stores eCommerce Knowledge Objects (eCKOs), populated from databases, Web sources, buyers, sellers, and other sources.
- *Markup Toolkit* – supports document markup using ontologies and DAML
- *Ontology Toolkit* – supports the authoring of ontologies in DAML and their use by the eCommerce Knowledge Base to represent eCKOs
- *Portal Toolkit* – supports the DAMLGate Web portal that enables manufacturers and vendors to access information stored in the eCommerce Knowledge Base and drilldown to details in the original information sources, including the eGateway and eServices databases, vendor extranets, etc.

This is the first of our two-stage approach to the DAMLGate project. We implemented this stage in three phases. In phase 1 we established the baseline requirements and ontology domains on which the DAMLGate architecture was crafted. The architecture was designed to support a wide variety of B2B eCommerce applications. The domain, process, time, and other ontological models of global B2B eCommerce were developed in the next phase. The ontologies are based on the DAML-S Web Services Markup Language, which is erected on the DAML+OIL infrastructure. We also populated the DAMLGate architecture with scalable component agent modules that are built on existing and emerging standards in this phase. DAML-S enables automated Web service discovery by encoding the properties and capabilities of a Web service so that those services can be either

included in a larger registry, or indexed and retrieved via a search engine or matchmaking system [14].

Although we used the Ontology Markup Assistant (OMA) and other automated markup protocols to aid our ontology construction effort, we endeavored to follow a systematic process in building our ontologies. In particular, we applied a hybrid of the METHONTOLOGY and SENSUS methodological frameworks [15] in building of our domain, process, and other ontologies. We formulated the hybrid ontological engineering framework because the existing methodologies are largely immature. Most of these methodologies are not adequate for building large open systems, such as the DAMLGate suite. The hybrid framework was used to address the architectural independence, robustness, scalability and other issues more effectively.

We considered four types of software agents in building the DAMLGate suite: information, modeling, planning, and brokering agents. We trained information agents to monitor databases, locate and extract information from the Web, filter raw sensor data feeds for relevant information and so on. These agents obtained real data derived from observations of the varying state of the electronics market. The modeling agents used the observations to estimate supply, demand or other state in the value chain and tracked data and material flow throughout the chain. We used planning agents to analyze all relevant market data and formulate an action plan for necessary intervention in the e-market. The planning agents were also trained to consummate a transaction between a buyer and a vendor in the value chain. The brokering agents performed coordinative roles, dynamically locating and linking of other agents, and enabling interoperability between the different constituent agents.

The major activities we undertook in the third phase of the initial stage of this project include the design and construction of an Oracle 9i database at the back-end, with a front-end Web interface, as well as prototyping and testing of DAMLGate. The database was built using a schema-based hierarchy of dependencies [16]. A major challenge we encountered in the database design related to capturing and loading metadata in DAMLGate. Initially, the Knowledge Object-level metadata and the Assertion-level metadata were stored in the knowledge base. We are exploring the possibility of implementing a Java Data Objects (JDO) interface to enable transparent persistence [17].

2.2 Underlying Assumptions

It is expected that current WWW is evolving into the Semantic Web – "an extended web of machine-readable information and automated services going way beyond current capabilities" [3]. It is anticipated that "explicit representation of the semantics underlying data, programs, pages, and other web resources, will enable a knowledge-based web providing a qualitatively new level of service." Automated services associated with the Semantic Web will enhance end users' ability to meet their needs by significantly increasing their understanding of the relevant Web content. Therefore, the new Web will provide more accurate filtering, categorization, and search of information sources. It will deliver "an extremely knowledgeable system with various specialized reasoning services that will support us in nearly all aspects of our daily life -- making access to information as pervasive, and necessary, as access to electricity is today" [3].

Furthermore, it is assumed that network-enabled, information-provision services will constantly access active information sources and will greatly enhance information extraction and search, as well as provide more reliable end user support. The automated selection and combination of these reasoning services will require machine-understandable representation of semantics. Online ontological support for data, information and knowledge exchange will drive the Semantic Web. Effective information management and exchange will require automatic and thorough processing of the exponentially growing Web content. Ontologies will assume a preeminent role in B2B eCommerce, knowledge management, and other application domains, given their extensive use in describing "the structure and semantics of information exchange" [3]. It is also envisaged that agent technology will continue to provide a comprehensive foundation for the Semantic Web.

The B2B e-market opportunities will continue to expand rapidly, and the growing base of participants includes government agencies and commercial businesses in every sector of the U. S. and other national economies. The opportunities are prevalent in the disaggregated electronics industries where enterprises constantly handle thousands of different-size parts and products in various stages of production, originating from widely dispersed vendors. The enterprises are often confronted with the complex logistical challenge of determining the best path in the value chain for each part.

This study has observed an unprecedented level of collaboration in the global electronics industry as participants increasingly pool resources in their quest to enhance productivity and reduce costs. It is assumed that the number of electronics and other manufacturers embracing collaboration will continue to grow worldwide.

Table 1 illustrates the trend in B2B transactions in the United States, Europe, and Japan between 1998 and 2002. In 2002, B2B transactions in the United States alone will reach $1.7 trillion, and could exceed $3.5 trillion by 2007. According to the Gartner Group, global B2B eCommerce is rapidly expanding, and is expected to reach $8.5 trillion in 2005 from $433 billion in 2000.

Region	1998	1999	2000	2001	2002
US	50	180	400	750	1,700
Europe	40	60	180	450	1,000
Japan	20	40	50	190	400

Table 1. B2B eCommerce Totals for the US, Europe & Japan, 1998 – 2002 (in USD billions)

Source: Fortune Magazine

The B2B e-market growth is exponential; everyday new technologies emerge and the number of technical resources available to use and program these tools is not sufficient to meet the demand. A major strategic business assumption underlying the DAMLGate model formulation is that worldwide B2B eCommerce will continue to grow at aggressive rates through 2004, when e-business becomes the predominant means of marketing in many industries, causing a massive upswing in 2005 and driving fundamental changes to the way enterprises do business with each other. Also, it is assumed that e-market makers will drive nearly 40 percent of B2B eCommerce transactions in 2004. The probability of the market outcomes predicted above is estimated at about 20 percent. [18]

According to Bear Stearns, an estimated $438 billion in B2B transactions will be conducted through Internet market makers in 2003, and the increased efficiency through Internet transactions will result in an estimated $57 billion in cost savings [19]. In spite of the substantial benefits derivable from B2B eCommerce and its great potential for growth, the business models underlying B2B transactions are still immature and urgently improvement.

3. RESULTS and DISCUSSION

3.1 Major Accomplishments

A major achievement in the first stage of this project is the construction and deployment of the initial version of the DAMLGate solution suite. The gateway is located on the Web at http://damlgate.bowiestate.edu. The site was populated with information from a few e-marketplaces that reflect the diversity in the electronics industry as metadata in agile catalogs. We expanded the domain ontology to reveal an extensive hierarchy of dependencies that is dynamically generated in the gateway. The attractiveness of DAMLGate design is that additional programming is not required to expand or update the ontology hierarchy [20].

We crafted the architecture to support global business-to-business collaboration and exchange in the electronics industry based on the concept of distributed data and aggregated metadata. Figure 2 reveals the DAMLGate architecture.

There are two classes of users of DAMLGate's B2B eCommerce solution: Consumers or computer manufacturers (buyers of various categories of parts needed to build different classes of computer) and Vendors – sellers of computer components, subassemblies, and other parts. Some users are both buyers and sellers. The key components of DAMLGate are the eCommerce domain objects, which model entities in the electronics market. These objects encapsulate both domain data – obtained from distributed, heterogeneous data sources (including the external databases of collaborating vendors), and domain logic (business rules, etc.). The eCommerce Objects are stored persistently in the Repository layer [21].

The initial domain objects are **supply chain** and **demand chain**. Since it is the dominant component of the value chain, supply chain is the standard in the modeling of collaboration and exchange in the industry value chain. Supply chain is defined as "a complicated network of direct and indirect manufacturing and distribution professionals that provide you with the capability to design, manufacture, and deliver your products better, faster, and cheaper" [22].

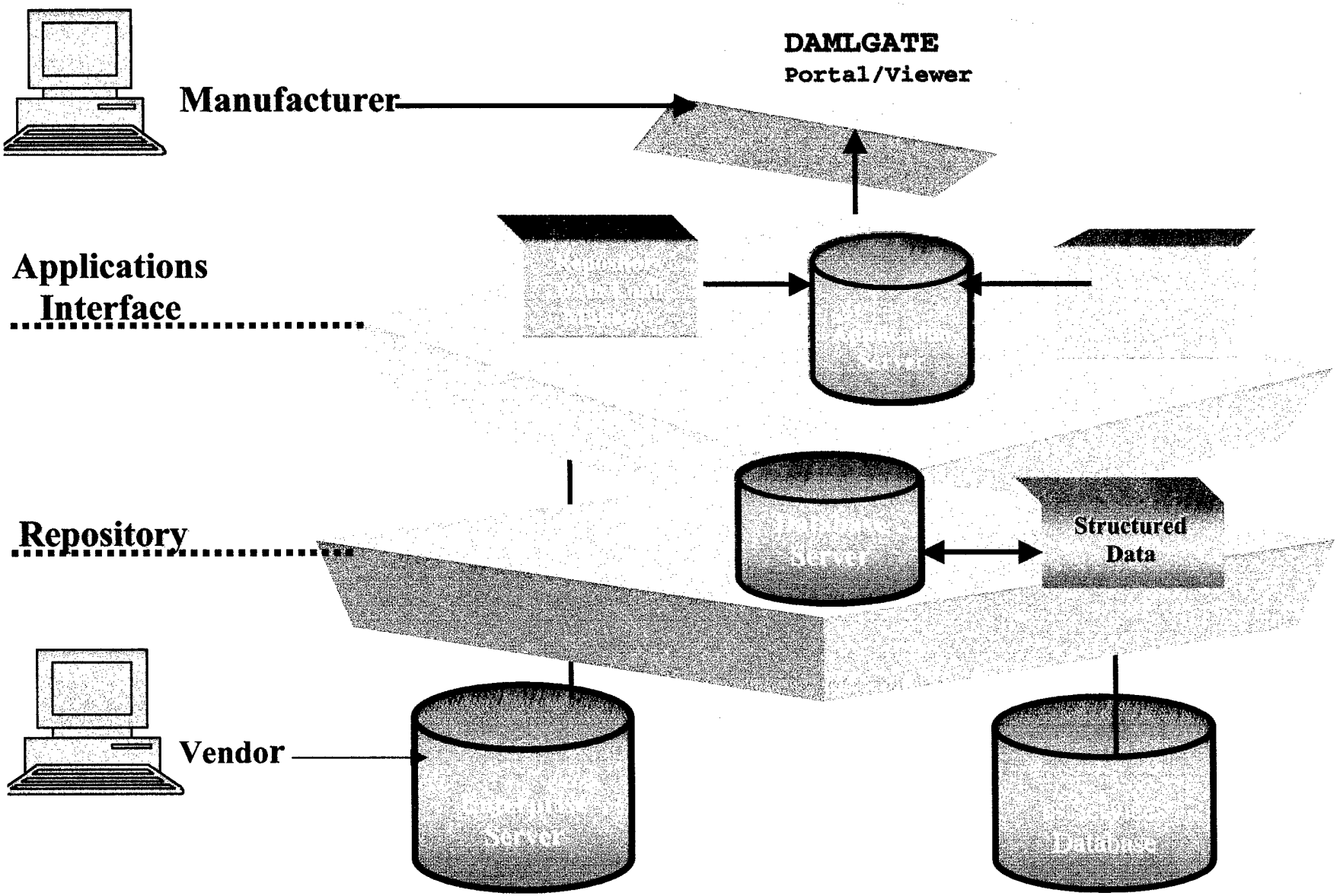

Figure 2. The DAMLGate Architecture

The demand chain represents the selling side of the industry value chain. Companies in the electronics and other industries are increasingly exploring the demand side for more opportunities for collaboration in their quest to increase productivity and reduce costs. For example, Compaq supports a global demand chain of more than 60,000 sales partners dispersed across 50 nations (and speaking 17 different languages) that generated about half of the company's $48 billion sales revenue in 2000 [22].

The DAMLGate Portal/Viewer layer comprises the portal and the viewer. Computer and other electronics manufacturers (the buyers) can browse objects using the portal/viewer layer, which is accessible through Microsoft Internet Explorer, Netscape Navigator, and other Web browsers. The portal provides a hierarchical view of agile catalogs of eCommerce objects the buyer can browse and search. The viewer displays the object hierarchies in spatial and tabular views. The Repository Access Manager is used to access the eCommerce objects uploaded from the Repository by the Repository Data Load Manager. The objects are populated from heterogeneous sources, including relational and other database systems.

The components of the portal are shown in Figure 3.

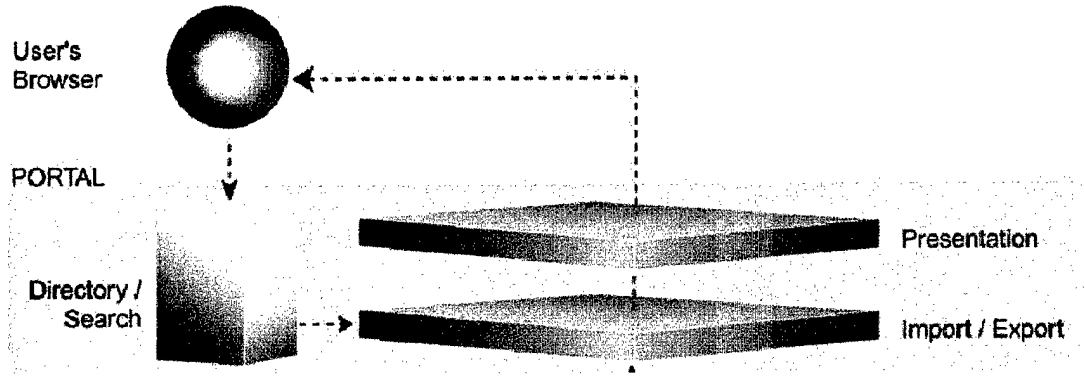

Figure 3. The DAMLGate Portal Architecture (derived from Bourdeaux [23])

The import/export tier provides an interface between the portal and applications and repository layers. The applications layer is currently populated with supply chain management (SCM), agile manufacturing, enterprise resource planning (ERP), workflow management, and customer relationship management (CRM) applications. The layer also contains a dynamic content management system, LAN mail services LAN mail, and other services. We plan to add decision support and advanced intelligent manufacturing systems in this layer in the next stage of the project. The repository layer includes the eServices, intelligent manufacturing, and external (user) databases as well as other information and data sources.

Publishing or presentation tier publishes information derived from a variety of data sources (including the Internet, intranet, or user extranets) to the portal interface. The information directory and search component maintains constantly updates the information stored in the agile catalogs. The manufacturers or other system users can query the common, dynamically extensible vocabulary/taxonomy/ ontology index through various search functions [23].

The project is advancing the primitive process model on which current buyer-seller transactions are based. The current model integrates the four-hemisphere B2B process model [24] for sourcing, procurement, workflow/supply chain management, and supplier relationship management with the strategic collaboration framework for the electronics industry [25].

3.2 Field Demonstration

The project initiated field demonstration of DAMLGate in March shortly after its Web server was installed on the project site. Because of the commercial orientation of the Process Ontology on which DAMLGate is erected the scope of participation of the prototype Web portal in the initial DAML Demonstration and Experiment Plan was limited.

4. CONCLUSIONS and RECOMMENDATIONS

4.1 Concluding Remarks

Agent technology will continue to provide a comprehensive foundation for the Semantic Web. This and other DAML projects have demonstrated that agent technology is indeed the best approach to achieving semantic interoperability between Web applications. Agent-based frameworks used in various DAML projects have greatly enhanced agent discovery, reuse, and interoperability. The enormous economic and other benefits derivable from the DAML tools and services provided by this project are driving major suppliers and other trading partners to DAMLGate and related initiatives, and will create a sustainable market for the digital services embedded in Semantic Web technologies.

It has been demonstrated that facilitating corporate access to critical Web content and services can greatly enhance personnel productivity and significantly reduce costs. Agent-based computing is playing a key role in enabling efficient derivation and effective use of information and other resources from the Web. As enterprises increasingly embrace B2B eCommerce, collaborating at various levels of business activity, new challenges emerge. The most outstanding challenge is posed by the inadequacy of current Web tools to enable optimum derivation of the benefits associated with virtual enterprise. The emerging Semantic Web tools provide Web data interoperability and are revolutionizing B2B eCommerce. However, the emerging agent technologies are not yet mature.

The DAMLGate experiment has proven that agent technology is an efficient way of dealing with digital overload. It has provided an innovative way of discovering, using, and interpreting Web resources. It provides a "one-stop shopping" to computer and other electronics equipment builders through the eGateway portal. The widespread acceptance of DAML+OIL (or the evolving OWL) as the standard for B2B eCommerce will depend on the rate at which the members of the B2B community adopt the philosophy of ontology-based markup of their products or services.

4.2 Recommendations

The growing complexity of modern manufacturing environments requires a broad suite of solutions that include optimization of data and material flow throughout the value chain. The solutions should provide decision support and content for procurement, product development, operations, and eCommerce between trading partners. This project recommends a Java-based agent platform for the development of such solutions.

4.3 Future Directions

Although the initial focus of this project is on the B2B electronic commerce, and global collaboration and exchange in the electronics industry value chain, in particular, we anticipate gradual adaptation of DAMLGate to other eCommerce domains and public use options. The missile or other major Defense-related manufacturing industry group would likely adopt DAMLGate. The missile industry already has considerable experience in the use of Web-agile supply chain management tools. The industry also provides opportunities for building sustainable computer-mediated relationships throughout its supply and value chain. Other potential users of the DAMLGate prototype include the aerospace, automotive, pharmaceutical, and shipbuilding industries. There is considerable evidence that these and many other commercial and non-commercial organizations are eager to deploy DAML or other Semantic Web tools.

Extension of the DAMLGate's eCommerce Ontology Manager design to handle business-to-consumer (B2C) and other eCommerce applications, as well as building the next generation eCommerce architecture and advanced e-business software tools are some of the next logical steps beyond the first stage of this project. We will continue to enhance the interconnectivity of DAML tools with other existing or emerging e-commerce applications and standards.

The lack of a common eCommerce ontological framework poses a major problem in the provision of cross-enterprise information management services in a rapidly evolving e-commerce environment. We intend to contribute to the search for a solution to this problem in the next stage of this project.

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LIST OF ABBREVIATIONS AND ACRONYMS

ABC	Agent-Based Computing
B2B	Business-to-Business eCommerce
B2C	Business-to-Consumer eCommerce
BSU	Bowie State University
CORBA	Common Object Request Broker Architecture
DAML	DARPA Agent Markup Language
DAML-S	DARPA Agent Markup Language for Web Services
DARPA	Defense Advanced Research Projects Agency
DTD	Document Type Definition (used in XML)
EC	Electronic Commerce
eCKO	eCommerce Knowledge Object
EDI	Electronic Data Interchange
EDIFACT	Electronic Data Interchange for Administration, Commerce, and Transport.
FTP	File Transfer Protocol
HTML	Hypertext Markup Language
HTTP	Hypertext Transfer Protocol
HTTPS	Hypertext Transfer Protocol run over the Secure Sockets Layer (SSL) protocol
IEEE	The Institute of Electrical and Electronics Engineers
IOTP	Internet Open Trading Protocol
IP	Internet Protocol

ISO	International Organization for Standardization
ISP	Internet Service Provider
JDO	Java Data Object
LAN	Local Area Network
OBI	Open Buying on the Internet
OIL	Ontology Inference Layer
OMA	Ontology Markup Assistant
OSI	Open System Interconnection
OSS	Operational Support System
OWL	Web Ontology Language
PIP	Partner Interface Process
PKC	Public Key Certificate
PKI	Public Key Infrastructure
PMI	Privilege Management Infrastructure
RDF	Resource Description Framework
RDF-S	Resource Description Framework Schema
SET	Secure Electronic Transaction
SLA	Service Level Agreement
UML	Unified Modelling Language
URI	Uniform Resource Identifier
URL	Uniform Resource Locator
XML	Extensible Markup Language

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